

Progress Report

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Entitled:

EOS Validation Activity in a Desert Encroachment Zone of sub-Sahel Africa

Principal Investigator:

*Rachel T. Pinker
Department of Meteorology
University of Maryland
College Park, Maryland 20742
Tel: 301-405-5380
Fax: 301-314-9482
e-mail: pinker@atmos.umd.edu*

Co-Investigator:

Professor T. O. Aro
Department of Physics
University of Ilorin
Ilorin, Nigeria

Background

Under this activity observations at a site in sub-Sahel Africa have been undertaken, to obtain information on geophysical parameters that are required for monitoring climate change and in support of NASA's Mission to Planet Earth goals, as related to instruments such as CERES, TRRM, MODIS and other. The data will help to improve the evaluation of products derived currently from satellites and as will become available from EOS Instrument Science Teams. In particular, it is aimed to obtain information on aerosol optical depth and the key components of the surface radiation budget, at an accuracy that meets the requirements of the WCRP Baseline Surface Radiation Network (BSRN). The site is located on the campus of the University of Ilorin, Nigeria, in the transition zone between the Sahara desert and the savanna zone of upper Nigeria. This is a climatically important region due to its location in a desert transition zone and due to the influence of the dusty Harmattan wind which is persistent for prolonged periods of time, and characterized by steady dusty conditions with high aerosol loading. The supervision of the daily operation is done by personnel of the University of Ilorin; instrument calibration, supervision, local personnel training, data quality check and data transfer to designated centers, is done by personnel of the University of Maryland, in coordination with Dr. E. Dutton, Director of BSRN; while the data analysis is a joint effort.

1. Progress Report on last year activity

During the last year, activity centered on data evaluation; calibration of instruments that were brought back from the site; preparation of presentations and manuscripts; input for "Sixth BSRN Science and review Workshop" (WCRP Informal report No. 17/2001); training of new student; work with data users of observations at Ilorin; and manuscript preparation. Specifically, homogeneous and quality controlled data have been prepared for the period November 1988 to June 1999. The pyranometers and pyrgeometer at the site were replaced with recently calibrated instruments. The instruments that are brought back from the site are calibrated at the University of Maryland and some, at Boulder, within the group of Dr. E. Dutton, to maintain reference calibration to same standards.

1.1 Preparation of manuscripts

Manuscripts prepared, revised and accepted:

1. Pinker, R. T., P. Govindand, B. N. Holben, O. Dubovik, and T. O. Aro, 2001. Importance of Observing Dust Aerosol Properties in Real-Time. J. Geophys. Res. Vol. 106, No. D19, p. 22,923.
2. Pandithurai, G, R. T. Pinker, O. Dubovik, B. N. Holben, and T. O. Aro, 2001. Remote Sensing of Dust Optical Characteristics in Sub-Sahel, West Africa. In press, JGR.
3. Holben, B. N., D. Tanre, A. Smirnov, T. F. Eck, I. Slutsker, N. Abuhassen, W. W. Newcomb, J. Schafer, B. Chatenet, F. Lavenue, Y. J. Kaufman, J. Vande Castle, A. Setzer, B. Markham, D. Clark, R. Frouin, R. Halthore, A. Karnieli, N. T. O'Neill, C. Pietras, R. T. Pinker, K. Voss, G. Zibordi, 2001. An emerging ground-based aerosol

climatology: Aerosol Optical Depth from AERONET. JGR, Vol. 106, No. D11, 12,067-12,097.

1.2 Work with data users of observations at Ilorin

Selected Manuscripts that use data from the Ilorin EOS validation site:

Morcrette, J.-J., 2001. The Surface Downward Longwave Radiation in the ECMWF Forecast System. ECMWF Technical Memorandum No. 339.

Knapp, K. R. and L. L. Stowe, 2001. Aerosol Optical Depth Retrieval over Land from AVHRR Pathfinder Atmosphere Data. GACP JAS Special Issue.

The pyrgeometers in use at Ilorin participated in an international calibration campaign, as described in:

Philipona, R., E. G. Dutton, T. Stoffel, J. Michalsky, I. Reda, A. Stifter, P. Wendling, N. Wood, S. A. Clough, E. J. Mlawer, G. Anderson, H. E. Revercomb, and T. R. Shippert, 2001. Atmospheric Long wave Irradiance Uncertainty: Pyrgeometers compared to an Absolute Sky-scanning radiometer, AERI and Radiative Transfer Model Calculation. In press, JGR.

1.3 Selected findings

A heavy dust event in the sub-Sahel during January 2000 was documented from observations made at the University of Ilorin, Ilorin (08° 19' N, 04° 20' E), Nigeria, in cooperation with the Aerosol Robotic Network (AERONET) (Holben et al., 1998; Pinker et al., 2001). Analysis of the observations in seven wavelengths, revealed that during the dust outbreak event, the optical properties of the dust aerosols were much different from what is assumed in aerosol climatologies in desert areas, or from observations preceding the dust event. Aerosol optical depths at all seven wavelengths showed a sharp increase when compared to the average for the season, reaching values up to 3.5 at 500 nm (Figure 1). The Angstrom exponent was reduced from 1.2 to 0.3 (Figure 2). The daily mean size distributions observed during the dust outbreak of January 29–February 1, when large amounts of coarse and fine particles were transported to the site, are presented in Figure 3 showing an order of magnitude increase in volume size distribution can be seen. The volume size distribution was retrieved from the direct solar and diffuse sky radiance measurements as discussed in Dubovik and King (2000). Temporal variation of single scattering albedo as observed on a typical day when biomass burning was reported in areas surrounding the experimental site is illustrated in Figure 4. During the morning hours, before the presence of aerosols from biomass burning, ω_0 increases with increasing wavelength. When biomass burning started (reported at 1 p.m. by local observers), the single scattering albedo values dropped and the spectral dependence reversed.

Using a two-year record of continuous ground-based measurements at the Ilorin site, desert aerosol models as presented in the literature are augmented, to better characterize the prolonged dust outbreak season in West Africa, which overlaps with the biomass-burning season. In Table 1, observed average values of aerosol optical depth are compared with those from other sources.

Table 1: “Sub-Saharan ” aerosol model: spectral aerosol optical depths and precipitable water vapor information.

Season	τ_a (440)	τ_a (500)	τ_a (670)	τ_a (870)	τ_a (1020)	P.W.V. (cm)
Harmattan (Nov-Mar)	0.895	0.830	0.695	0.602	0.558	2.787
		0.59 ¹	0.653 ²			2.76 ²
		0.29 ⁵	0.485 ⁴			1.35 ³
		0.333 ⁶				1.13 ⁴
Non-Harmattan (Apr-Oct)	0.476	0.455	0.405	0.372	0.363	4.620
		0.431 ¹	0.704 ⁴			2.75 ³
		0.19 ⁵				3.84 ⁴
		0.273 ⁶				

¹d’Almeida (1987), measurements made at Zaria, Nigeria during 1981-82.

²Faizoun et al. (1994), measurements made at Ouangofitini during 1985-87.

³Tuller (1968).

⁴Faizoun et al. (1994), measurements made at Bidi during 1987-89.

⁵Tegen et al. (1997), obtained from monthly mean totals of nine individual species, derived from a transport models, in a grid cell over Ilorin, Nigeria.

⁶Values from the Global Aerosol Data Sets (GADS) by Koepke et al., (1997) for winter (0% RH) and summer (70% RH), at 500 nm over a 10N, 5E grid box.

In Table 2, observed average values of single scattering albedos during the Harmattan and non-Harmattan seasons are compared with those from other sources.

Table 2: “Sub-Saharan ” aerosol model: single scattering albedo

Season	$\omega_o(440)$	$\omega_o(670)$	$\omega_o(870)$	$\omega_o(1020)$
Harmattan	0.880	0.887	0.887	0.889
	0.71 ¹	0.75 ¹	0.72 ¹	
	0.71 ²	0.92 ²		
Non-Harmattan	0.929	0.932	0.935	0.938
	0.75 ¹	0.79 ¹	0.83 ¹	

¹d’Almeida (1987).

²Carlson and Caverly (1977).

Comparisons were done with aerosol optical depths as derived from satellite observations, such as the TOMS instrument. To compare with the TOMS aerosol index, which is derived mainly from the 340 and 380 nm reflectances, CIMEL observed aerosol optical depths at 340 nm were grouped into daily means for two years (from April 1998–March 2000). TOMS aerosol index over Ilorin, Nigeria was computed by taking weighted means from four neighboring grids of 1-degree spatial resolution. A comparison of daily mean AOD at 340 nm and TOMS aerosol index is shown in Figure 5, illustrating good agreement in the detection of the dust outbreak. Precipitable water vapor that was retrieved using direct sun measurements at 940 nm (Bruegge et al., 1992), exhibits significant seasonal variation and agrees well with the NCEP reanalysis values (Figure 6). Seasonal means of AODs are negatively correlated with precipitable water vapor.

During the next year, we plan to:

- continue current activity, which requires site visit, on site training, data reduction and distribution, correcting problems with instrumentation, and recalibration
- conducting transect measurements of aerosol properties north of Ilorin, and closer to the Sahel, using the new MICROTOPS instruments, to be done by a graduate student at Ilorin

- prepare manuscripts (e. g., dust-aerosol forcing)

References:

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Dubovik, O., and M. D. King, A flexible inversion algorithm for retrieval of aerosol optical properties from Sun and sky radiance measurements, *J. Geophys. Res.*, 105, 20,673-20,696, 2000.

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Koepke, P., M. Hess, I. Schult, and E. P. Shettle, Global Aerosol Data Set (GADS), MPI Meteorologie Hamburg Report No. 243, 44 pp, 1997.

Tegen, I., P. Hollrig, M. Chin, I. Fung, D. Jacob, and J. Penner, Contribution of different aerosol species to the global aerosol extinction optical thickness: Estimates from model results, *J. Geophys. Res.* 102, 23895-23915, 1997.

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